



Environmental Impacts of the Use of Orimulsion®

**Report to Congress
on Phase 1 of the
Orimulsion® Technology
Assessment Program**

**Volume 1: Executive
Summary, Report, and
Appendix A**

Foreword

The U.S. Environmental Protection Agency is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

E. Timothy Oppelt, Director
National Risk Management Research Laboratory

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**Environmental Impacts of the
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**Report to Congress on
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Assessment Program**

**Volume 1. Executive Summary, Basic
Report, and Appendix A**

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Abstract

Orimulsion, a bitumen-in-water emulsion produced in Venezuela, was evaluated to provide a better understanding of the potential environmental impacts associated with its use as a fuel. A series of pilot-scale tests were conducted at the U.S. Environmental Protection Agency's Environmental Research Center in Research Triangle Park, NC, to provide data on emissions of air pollutants from the combustion of Orimulsion 100 (the original formulation), Orimulsion 400 (a new formulation introduced in 1998), and a No. 6 (residual) fuel oil. These results, and results of full-scale tests reported in the technical literature, were evaluated to determine the potential air pollutant emissions and the ability of commercially available pollution control technologies to adequately reduce those emissions. Emissions of carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur dioxide (SO₂), sulfur trioxide, particulate matter (PM), and organic and metal hazardous air pollutants (HAPs) were measured from each of these three fuels to provide a comparison between the "new" fuel (Orimulsion) and a fuel that has been commonly used in the U.S. (the No. 6 fuel oil). Results indicate that CO, NO_x, and PM emissions are likely to be nearly the same as those from the No. 6 fuel oil, that SO₂ emissions can increase if the fuel sulfur content increases, that the particles generated by Orimulsion 100 and 400 are likely to be smaller in diameter than those generated by No. 6 fuel oil, and that HAPs are also likely to be similar to those from No. 6 fuel oil. Both the full-scale results found in the literature and the pilot-scale results measured at EPA indicate that conventional air pollution control technologies can effectively reduce emissions to very low levels, depending upon the type of technology used and the desired emission levels. Because the bitumen in Orimulsion is heavier than water and due to the presence of a surfactant in the fuel, spills of Orimulsion are likely to be more difficult to contain and recover than are spills of heavy fuel oil, especially in fresh water. Additional study is needed before adequate containment and response approaches can be developed. Little, if any, work has been conducted by the fuel producer or the scientific community to address the remaining spill-related issues.

Preface

This report is the result of a request by the U.S. Congress to receive scientific information regarding the potential environmental impacts of the use of Orimulsion as a fuel. In the second half of the 1990s, there was considerable interest on the part of electric utilities in using Orimulsion, which was promoted as a low-cost fuel that could replace heavy fuel oil or coal. There were also many concerns raised by the environmental community regarding the environmental impact associated with switching to Orimulsion. In 1997, the U.S. Congress requested that the U.S. Environmental Protection Agency (EPA) conduct a study to evaluate the potential environmental impacts associated with the use of Orimulsion. EPA's Office of Research and Development provided funds to the National Risk Management Research Laboratory (NRMRL) to conduct this study, and a team of EPA experts in air pollution control, spill response, health effects, and environmental assessment was assembled to carry out the investigation. This report was prepared by EPA staff using data generated at EPA facilities as well as data collected from the general literature.

In 1998, Bituménés Orinoco (Bitor), the manufacturer of Orimulsion, changed the formulation of the fuel. The original fuel, renamed Orimulsion 100, was replaced with a new formulation named Orimulsion 400. Compared to the amount of information on Orimulsion 100, there is relatively little data on the performance of Orimulsion 400. While this report provides as much data as possible on the emissions and performance of Orimulsion 400, the bulk of the data are for the older formulation (Orimulsion 100). Although Orimulsion 100 is no longer produced, the results presented here are still believed to adequately describe the basic behavior of both formulations of Orimulsion. The key question to be addressed in this study is, "Is Orimulsion significantly different from other fossil fuels, and if so, how?" The differences between Orimulsion 100 and Orimulsion 400, as indicated both from the available data and the information provided by the manufacturer, are substantially smaller than the differences between Orimulsion and other fossil fuels. The report distinguishes between the two formulations where appropriate, but uses the generic term "Orimulsion" where such distinction is either unimportant or misleading. The recent reformulation is significant with respect to the surfactant used (which will affect spill toxicity) and the use of a magnesium-based additive (which will affect boiler tube deposition and particulate matter emissions). Other environmental issues appear to be impacted only to a minor degree by the change in formulation.

The emphasis of this report is on generation and control of air pollutants from the combustion of Orimulsion. Although there are other environmental issues associated with the use of Orimulsion, particularly spills of the fuel into water, EPA and NRMRL were advised on several occasions that questions related to air pollutant generation and control were the key unknowns associated with understanding the environmental impact potential of Orimulsion. The initial step in EPA's research activities was the convening of a workshop to discuss environmental issues related to Orimulsion use. This workshop, held February 8, 1998, concluded that there was a lack of information on particle size distribution and composition and on emissions and control of sulfur trioxide from Orimulsion combustion. The workshop also concluded that enough data existed to allow a comparative risk analysis for heavy fuel oil and Orimulsion, and therefore additional research in that area was not immediately required. The workshop noted that a lack of data existed describing the behavior, fate, and effects of Orimulsion spills in fresh water. However, the workshop concluded that investigations into these areas should be the responsibility of Bitor in the event they sought to market the fuel to users where spills into fresh water were possible. Considerable work has been conducted to quantify behavior, fate, and effects of Orimulsion in saltwater environments under the oversight of the International Orimulsion Working Group, of which Bitor is a member and the major source of funding. Thus this report has as its focus the generation and control of air pollutants, although other topics are also covered.

This focus was emphasized in the Orimulsion Technology Assessment Plan that was prepared to guide EPA's research efforts. This plan was reviewed and approved, with modifying comments, by a

panel of technical experts, mostly from outside the federal government. The only exception was one member from the U.S. Coast Guard. The Plan was then reviewed by the Office of Management and Budget (OMB), the U.S. Department of Energy, and the Office of Science and Technology Policy. EPA responded to comments made by each of these organizations and revised the Plan, which was approved by OMB on April 22, 1999.

The National Risk Management Research Laboratory was the lead organization for the study, and was chiefly responsible for preparation of Chapters 1-5 and 9-12. Robert E. Hall was the overall program lead, and C. Andrew Miller was the lead author of these chapters. Kevin Dreher of the National Health and Environmental Effects Research Laboratory prepared Chapter 6, on toxicity testing, with substantial assistance from Adriana Crain. Chapter 7, on spills, was prepared with assistance from Royal J. Nadeau of EPA's Office of Solid Waste and Emergency Response. Randall Wentzel of the National Center for Environmental Assessment prepared Chapter 8, on environmental assessment.

The conclusions stated in this report are scientific conclusions, and are not intended to provide guidance relative to regulatory requirements that may or may not apply to the use of Orimulsion.

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Many of the reports from which full-scale data were taken were provided by Nelson Garcia Tavel of Bitor America, Jason Miles of Bitor Europe, and independent consultant Ken Olen.

Nomenclature and Acronyms

APCS	air pollution control system
API	American Petroleum Institute
APPCD	Air Pollution Prevention and Control Division
ARD	Arizona road dust
ASTM	American Society for Testing and Materials
BALF	bronchoalveolar fluid
bbl	barrels, U.S. petroleum
BTEX	benzene, toluene, ethylene, and xylenes
Btu	British thermal unit
CAA	Clean Air Act
CAAAAs	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CE	Combustion Engineering
CEM	continuous emission monitor
CO	carbon monoxide
CO ₂	carbon dioxide
DAS	data acquisition system
DQI	data quality indicator
EDX	energy dispersive x-ray
ENEL	Italian Electricity Generating Board
EPA	Environmental Protection Agency
ESP	electrostatic precipitator
FETC	U.S. Department of Energy's Federal Energy Technology Center
FGD	flue gas desulfurization
FPL	Florida Power & Light Company
GIS	geographical information systems
HAP	hazardous air pollutant
HEPA	high efficiency particulate air
HFO	heavy fuel oil
HQ	health quotient
IOWG	International Orimulsion Working Group
IURE	inhalation unit risk estimate
LAPIO	low API oil
LDH	lactate dehydrogenase
LNB	low NO _x burner
LOEC	lowest observable effects concentration
LOEL	lowest observed effect level
LOI	loss on ignition
MACS	miniature acid-condensation system
MDL	method detection limit
MEI	maximum exposed individual
MIR	maximum individual risk
NCEA	National Center for Environmental Assessment
NHEERL	National Health and Environmental Effects Research Laboratory
NO	nitric oxide
NOEC	no observable effects concentration
NO _x	nitrogen oxides
NRC	National Research Council

Nomenclature and Acronyms (Continued)

NRMRL	National Risk Management Research Laboratory
NSPS	New Source Performance Standard
O ₂	oxygen
OERR	Office of Emergency and Remedial Response
OFA	overfire air
ORD	Office of Research and Development
ORI 100	Orimulsion 100
ORI 400	Orimulsion 400
OSWER	Office of Solid Waste and Emergency Response
OTAP	Orimulsion Technology Assessment Plan
PAH	polycyclic aromatic hydrocarbon
PBS	Package Boiler Simulator
PC	pulverized coal
PDVSA	Petróleos de Venezuela, S.A.
PEA	performance evaluation audit
PM	particulate matter
PM _{2.5}	particulate matter smaller than 2.5 µm in aerodynamic diameter
PM ₁₀	particulate matter smaller than 10 µm in aerodynamic diameter
ppm	parts per million
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
ROFA 6	residual oil fly ash (No. 6 fuel oil)
RSD	relative standard deviation
SASS	source assessment sampling system
SCR	selective catalytic reduction
SEM	scanning electron microscope
SMPS	scanning mobility particle sizer
SNCR	selective noncatalytic reduction
SO ₂	sulfur dioxide
SO ₃	sulfur trioxide
SVOC	semivolatile organic compound
TCLP	toxicity characteristic leaching potential
THC	total hydrocarbon
TSA	technical systems audit
VOC	volatile organic compound
VOST	volatile organic sampling train
WLFO	wet limestone forced oxidation
XRF	X-ray fluorescence

Contents

Volume 1

	<u>Page</u>
Abstract	ii
Preface	iii
Acknowledgments	iv
Nomenclature and Acronyms	v
List of Figures	xiii
List of Tables	xvi
Executive Summary	ES-1
Conclusions of the Report	ES-1
Recommendations of the Report	ES-1
Purpose and Approach	ES-2
Background	ES-3
Air Emissions	ES-3
Data from EPA Pilot-Scale Tests	ES-3
Toxicity Testing	ES-4
Spills	ES-5
Risk Assessment	ES-5
Potential Use of Orimulsion	ES-6
1. Introduction and Background	1-1
Background	1-1
Overview of Orimulsion and its Use	1-2
Air Emissions	1-3
Spills	1-4
Objective	1-5
Approach	1-5
Report Structure	1-6
2. Properties and Characteristics of Orimulsion	2-1
Background	2-1
Properties of Emulsified Fuels	2-1
Combustion Behavior	2-1
Impact on Boiler Efficiency	2-2
Fuel Handling	2-3
Properties of Orimulsion	2-3
Fuel Composition	2-4
Fuel Handling	2-4
Temperature	2-4
Shear	2-4
Contamination	2-6
Evaluating Environmental Issues Associated With Orimulsion Combustion	2-6
Air Emissions	2-7
Solid Residues	2-9
3. Review of Previous Orimulsion Combustion Research and Demonstration	3-1
Fundamental Studies	3-1

Contents (Continued)

	<u>Page</u>
Pilot-Scale Testing	3-2
Combustion Performance	3-2
Burner Development	3-4
Trial Tests	3-4
Reburning Development	3-6
Air Pollution Control Equipment Evaluation	3-6
Full-Scale Testing and Operation	3-7
Plants Currently Operating	3-7
New Brunswick Power Dalhousie Generating Station	3-8
Dalhousie Demonstration Tests	3-8
Conversion to Permanent Orimulsion Operation	3-11
Use of Orimulsion 400	3-12
Kansai Electric Power Company Osaka No. 4	3-14
Kashima-Kita Electric Power Company	3-14
SK Energy Asnaes Unit 5	3-14
Orimulsion 100 Use at Asnaes	3-14
Orimulsion 400 Use at Asnaes	3-18
ENEL Brindisi Sud Units 1 and 2 and Fiume Santo Plant	3-19
Past Operations	3-20
Florida Power & Light Company Sanford Plant	3-20
PowerGen Ince and Richborough	3-21
Energie-Versorgung Schwaben Marbach III Power Plant	3-23
Planned Operations	3-23
Reburning Development	3-24
Engineering Studies	3-25
Feasibility Studies	3-26
Pollution Control Equipment Analyses	3-27
Other Work	3-27
Diesel Engines	3-27
Gasification	3-27
Briquetting of Coal Fines	3-27
Cement Kilns	3-28
Desulfurization	3-28
Summary of Previous Work	3-28
Operational Issues	3-28
Fuel Handling and Atomization	3-28
Excess O ₂	3-28
Boiler Efficiency	3-28
Boiler Fouling	3-29
Air Emissions	3-29
CO	3-29
NO _x	3-29
SO ₂ and SO ₃	3-30
PM	3-31
Hazardous Air Pollutants and Metals	3-31
CO ₂	3-32
Air Pollution Control	3-34
NO _x Control	3-34
Low NO _x Burners	3-34
Reburning	3-34
Selective Catalytic Reduction	3-34

Contents (Continued)

	<u>Page</u>
SO ₂ and SO ₃ Control	3-35
PM Control	3-35
ESPs	3-35
Baghouses	3-35
Solid Residue Disposal	3-36
 4. EPA Pilot-Scale Experimental Approach and Equipment	 4-1
Approach	4-1
Test Equipment	4-1
Package Boiler Simulator	4-1
Fuel Supply System	4-2
Instrumentation	4-2
Continuous Emission Monitors	4-3
Data Acquisition System	4-4
Dilution Sampling System	4-5
Scanning Mobility Particle Sizer	4-6
Scanning Electron Microscope	4-7
Sampling Methods	4-7
EPA Methods 5 and 29	4-7
EPA Methods 0010 and 0030	4-8
Modified CARB Method 501	4-8
 5. EPA Pilot-Scale Test Results	 5-1
Test Conditions	5-1
Fuel Composition	5-1
O ₂	5-1
Fuel Feed	5-1
Emission Measurement Results	5-3
CO	5-3
NO _x	5-5
SO ₂ and SO ₃	5-5
PM	5-7
Organic HAPs	5-10
Volatile Organic Compounds	5-10
Semivolatile Organic Compounds	5-11
Metals	5-14
Emission Factors	5-18
Scanning Electron Micrographs	5-21
 6. Physicochemical Properties and Acute Pulmonary Toxicity of Orimulsion Fly Ash	 6-1
Objective	6-1
Oil Fly Ash Production and Collection	6-1
Reference Particle	6-1
Physicochemical Properties of Oil Fly Ash Samples and Arizona Road Dust	6-1
Acute Pulmonary Toxicity of Oil Fly Ash and Arizona Road Dust Samples	6-2
Oil Fly Ash Health Effects Commentary	6-5
 7. Spills	 7-1
Introduction	7-1
Background	7-1

Contents (Continued)

	<u>Page</u>
Reported Orimulsion Spill Studies	7-4
Saltwater Spills	7-5
Freshwater Spills	7-5
Data Gaps	7-7
8. Environmental Risk Assessment	8-1
Comparative Ecological Risk Assessment Evaluation	8-1
Introduction	8-1
Summary of Comparative Ecological Risk Assessment Reports	8-2
Scope of Harwell Work	8-2
Approach of Harwell Work	8-2
Conclusions of Harwell Work	8-2
Scientific Evaluation of the Comparative Ecological Risk Assessment of Spills from No. 6 Fuel Oil and Orimulsion 100	8-3
Overview of Harwell Assessment	8-3
Assessment Methodologies	8-3
Portability of this Assessment to Other Sites	8-7
Fate and Transport Methods	8-8
Toxicity Test Methods	8-8
Suggested Improvements for the Tampa Bay Risk Assessment	8-9
Toxicology	8-9
Benthic Community	8-10
Modeling	8-10
Mitigation	8-10
Assessment of Risk from Air Emissions	8-10
Conclusions	8-12
9. Comparison of Orimulsion with Other Fossil Fuels	9-1
Fuel Properties	9-1
Coal	9-1
Fuel Oil	9-2
Natural Gas	9-3
Fuel Use	9-4
Coal	9-5
Fuel Oil	9-5
Natural Gas	9-8
Air Pollutant Emissions and Control	9-8
CO Emissions and Control	9-8
NO _x Emissions and Control	9-9
SO _x Emissions and Control	9-11
PM Emissions and Control	9-13
Hazardous Air Pollutants Emissions and Control	9-16
Transition Metals Emissions and Control	9-18
CO ₂ Emissions	9-18
Summary of Air Pollutant Emissions	9-19
10. Quality Assurance	10-1

Contents (Continued)

	<u>Page</u>
Data Reported in Literature	10-1
In-House Combustion Testing	10-1
Data Quality Indicator Goals	10-1
Calculation of DQI Values	10-3
Sampling Goals	10-3
Analytical Data Quality Indicators	10-3
Volatile Organic Compounds	10-3
Semivolatile Organic Compounds	10-4
Metals Analyses	10-9
Audits	10-10
Audit Summary	10-10
Findings and Observations	10-12
EPA Performance Evaluation and Systems Audits	10-12
Flue Gas Flow	10-12
Fuel Input Flow	10-13
CEM Calibrations	10-13
Other Discrepancies	10-13
ARCADIS Technical Systems Audit	10-14
Other Discrepancies	10-14
Data Limitations	10-14
QA Review of Sampling and Measurement Activities at Asnaes	10-15
Flue Gas Concentration Measurements	10-15
PM Sampling Program	10-16
Toxicity Testing	10-17
 11. Conclusions and Recommendations	 11-1
Responses to Questions of the Peer Panel	11-1
Further Conclusions	11-3
Orimulsion Properties	11-3
Air Pollutant Emissions	11-3
Air Pollution Control Technologies	11-3
Solid Waste Disposal	11-3
Toxicity	11-3
Spills	11-3
Ecological Risk	11-3
Potential for Orimulsion Use	11-4
Data Reported in the Literature	11-4
Recommendations	11-4
 12. References	 12-1
 APPENDIX A. Conversion of English System to SI System Units	 A-1
Volume 2	
 APPENDIX B. Continuous Emission Monitoring Data for EPA Pilot Scale Tests	 B-1
APPENDIX C. Volatile Organic Compound Analysis Laboratory Reports	C-1

APPENDIX D.	Semivolatile Organic Compound Analysis Laboratory Reports	D-1
APPENDIX E.	Metal Analysis Laboratory Reports	E-1
APPENDIX F.	Orimulsion Spill References Cited by the NRC, U.S. Coast Guard, and Environment Canada Reports	F-1
APPENDIX G.	Additional Ecological Risk Assessment Studies	G-1
APPENDIX H.	Comparative Risk Methodology Synopsis of Harwell et al. (1995)	H-1

List of Figures

Volume 1

	<u>Page</u>
1-1. Orinoco region of Venezuela	1-4
2-1. Types of instabilities in bitumen-in-water emulsions	2-6
3-1. Emissions of CO, NO _x , and PM measured during pilot-scale tests of Orimulsion 100 combustion	3-3
3-2. F-jet and advanced F-jet atomizers used in Orimulsion combustion tests at PowerGen's Power Technology Centre	3-5
3-3. Photograph of Dalhousie Generating Station, Dalhousie, New Brunswick, Canada	3-8
3-4. Particle size distribution for PM emitted from the combustion of heavy fuel oil and Orimulsion 100 during demonstration testing at NB Power Dalhousie Generating Station	3-10
3-5. Carbon in ash in PM emitted from the combustion of heavy fuel oil and Orimulsion 100 during demonstration testing at NB Power Dalhousie Generating Station	3-11
3-6. CO as a function of stack O ₂ levels measured during combustion testing of heavy fuel oil and Orimulsion 100 at the NB Power Dalhousie Generating Station	3-12
3-7. Relationship between the acid dewpoint and SO ₃ emissions measured during Orimulsion 100 demonstration testing at the NB Power Dalhousie Generating Station	3-13
3-8. Relationship between stack and acid dewpoint temperature for each day during Orimulsion 100 demonstration testing at NB Power Dalhousie Station	3-13
3-9. CO, NO _x , and SO ₂ emissions at Kansai Electric Company Osaka No. 4 plant	3-15
3-10. Emissions of PM, unburned carbon, and SO ₃ at Kansai Electric Company Osaka No. 4 plant	3-16
3-11. Particle size distribution for PM from the combustion of Orimulsion 100 measured at SK Energy Asnaes Unit 5	3-17
3-12. NO _x emission rates as a function of load measured during testing of Orimulsion 100 at the Florida Power & Light Sanford Plant	3-21
3-13. Average PM emission rates as a function of test condition measured during testing of Orimulsion 100 at the Florida Power & Light Sanford Plant	3-22
3-14. NO _x emissions measured during the reburning demonstration at Hennepin Station . .	3-25
3-15. NO _x emissions measured during the reburning demonstration at Hennepin Station using natural gas and Orimulsion 100 as reburn fuel, as a function of % reburn fuel input	3-26
4-1. Schematic of Package Boiler Simulator	4-3
4-2. Schematic of fuel feed system for heavy fuel oil	4-4

List of Figures (Continued)

	<u>Page</u>
4-3. Schematic of fuel feed system for Orimulsion 100 and Orimulsion 400	4-5
4-4. Schematic of continuous emission monitoring system	4-6
4-5. Schematic of high volume dilution sampling system	4-7
5-1. Average CO emissions from the three fuels tested	5-4
5-2. CO vs. O ₂ for selected runs with Orimulsion 100, Orimulsion 400, and No. 6 fuel oil .	5-4
5-3. Average NO emissions from the three fuels tested	5-5
5-4. NO vs. O ₂ for selected runs with Orimulsion 100, Orimulsion 400, and No. 6 fuel oil .	5-6
5-5. Average SO ₂ emissions as measured by CEM from the three fuels tested	5-6
5-6. Average PM emissions from the three fuels tested	5-8
5-7. Cascade impactor results for the three fuels tested	5-9
5-8. Scanning mobility particle sizing results for the three fuels tested	5-10
5-9. Average detected concentration of volatile organic compounds	5-13
5-10. Average detected emission factors of volatile organic compounds	5-14
5-11. Average detected concentrations of semivolatile organic compounds	5-16
5-12. Average detected emission factors of semivolatile organic compounds	5-16
5-13. Concentrations of metals measured in the flue gases of the three fuels	5-17
5-14. Scanning electron micrograph of untreated blank filter at 700x magnification	5-22
5-15. Scanning electron micrograph of untreated filter loaded with PM from No. 6 fuel oil at 700x magnification	5-23
5-16. Scanning electron micrograph of untreated filter loaded with PM from Orimulsion 100 at 700x magnification	5-23
5-17. Scanning electron micrograph of untreated filter loaded with PM from Orimulsion 400 at 700x magnification	5-24
6-1. Particle-induced acute lung injury	6-4
7-1. Movement, spill volumes, and spill rates of heavy oils in U.S. domestic waters between 1991 and 1996	7-2
7-2. Spill of nonfloating oil in low-current fresh water	7-3
7-3. Spill of nonfloating oil in high-current fresh water	7-4
7-4. Spill of nonfloating oil in high-current salt water	7-5
9-1. Estimated recoverable reserves of coal in the U.S. by sulfur content	9-2
9-2. U.S. electricity generation in 1997 by fossil fuel	9-4
9-3. U.S. utility and industrial coal consumption in 1997 by state	9-6
9-4. U.S. fuel oil consumption by the commercial, industrial, oil company, and utility sectors in 1997 by state	9-7

List of Figures (Continued)

	<u>Page</u>
9-5. U.S. natural gas consumption by the commercial, industrial, and utility sectors in 1997 by state	9-10
9-6. Comparison of particle size distributions from the combustion of pulverized coal before and after an ESP	9-15
9-7. Particle size distributions for a No. 6 fuel oil and the same fuel oil in a 90% oil/10% water emulsion	9-17

Volume 2

B-1. CEM data for O ₂ , CO, NO, and SO ₂ taken May 18, 1999 during EPA's pilot scale testing of Orimulsion 400	B-2
B-2. CEM data for O ₂ , CO, NO, and SO ₂ taken May 19, 1999 during EPA's pilot scale testing of Orimulsion 400	B-3
B-3. CEM data for O ₂ , CO, NO, and SO ₂ taken May 20, 1999 during EPA's pilot scale testing of Orimulsion 400	B-4
B-4. CEM data for O ₂ , CO, NO, and SO ₂ taken May 21, 1999 during EPA's pilot scale testing of Orimulsion 400	B-5
B-5. CEM data for O ₂ , CO, NO, and SO ₂ taken May 24, 1999 during EPA's pilot scale testing of Orimulsion 100	B-6
B-6. CEM data for O ₂ , CO, NO, and SO ₂ taken May 25, 1999 during EPA's pilot scale testing of Orimulsion 100	B-7
B-7. CEM data for O ₂ , CO, NO, and SO ₂ taken May 26, 1999 during EPA's pilot scale testing of Orimulsion 100	B-8
B-8. CEM data for O ₂ , CO, NO, and SO ₂ taken May 27, 1999 during EPA's pilot scale testing of Orimulsion 100	B-9
B-9. CEM data for O ₂ , CO, NO, and SO ₂ taken June 3, 1999 during EPA's pilot scale testing of No. 6 fuel oil	B-10
B-10. CEM data for O ₂ , CO, NO, and SO ₂ taken June 4, 1999 during EPA's pilot scale testing of No. 6 fuel oil	B-11
B-11. CEM data for O ₂ , CO, NO, and SO ₂ taken June 7, 1999 during EPA's pilot scale testing of No. 6 fuel oil	B-12
B-12. CEM data for O ₂ , CO, NO, and SO ₂ taken June 8, 1999 during EPA's pilot scale testing of No. 6 fuel oil	B-13

List of Tables

Volume 1

	<u>Page</u>
ES-1. Summary of air pollutant concentrations reported in the literature for Orimulsion and heavy fuel oil	ES-4
2-1. Typical properties of Cerro Negro bitumen	2-3
2-2. Typical values and ranges of Orimulsion 100 properties and constituents	2-5
2-3. Radioactive elements present in Orimulsion	2-6
2-4. Metals and radioactive elements present in Orimulsion fly ash	2-9
2-5. Toxicity characteristic leaching procedure (TCLP) results for Orimulsion 100 and coal fly ashes	2-10
3-1. Flue gas composition for pilot-scale tests using a burner from Dunamenti Power Station	3-3
3-2. Plants that have operated or are were operating commercially as of December 2000 using Orimulsion	3-7
3-3. Emissions measured during Dalhousie Station Unit 1 Demonstration	3-9
3-4. Stack trace metal emissions in mg/Nm ³ measured at Asnaes Unit 5	3-17
3-5. Trace metal concentrations in Orimulsion 100 fly ash in mg/kg measured at Asnaes Unit 5	3-18
3-6. Trace metal concentrations in dry scrubber sludge samples taken during operation with coal and Orimulsion 100 from Asnaes Unit 5	3-19
3-7. Emissions of trace metal compounds during tests of Orimulsion 400 at ENEL Fiume Santo Plant	3-20
3-8. Comparison of long-term contributions to ambient concentration or deposition of pollutants from the combustion of Orimulsion 100 at Marbach III Power Plant . . .	3-24
3-9. CO emissions measured during pilot- and full-scale tests for heavy fuel oil and Orimulsion 100	3-29
3-10. NO _x emissions measured during pilot- and full-scale tests for heavy fuel oil and Orimulsion	3-30
3-11. Reported SO ₃ emissions measured during pilot- and full-scale tests for heavy fuel oil and Orimulsion	3-31
3-12. Reported PM emissions measured during pilot- and full-scale tests for heavy fuel oil and Orimulsion	3-32
3-13. Reported PM size distributions measured during pilot- and full-scale tests for heavy fuel oil and Orimulsion	3-33
3-14. Emissions of selected hazardous air pollutants from coal, heavy fuel oil, and Orimulsion	3-33
4-1. Test matrix for EPA pilot-scale tests of Orimulsion air pollutant emissions	4-2
5-1. Elemental analyses (as received) of the three fuels tested	5-2
5-2. Average O ₂ stack concentrations for each test run, and average of four test runs	5-2
5-3. Average fuel flows for each test run, and average of four test runs	5-3

List of Tables (Continued)

	<u>Page</u>
5-4. SO ₂ concentrations for the three fuels tested as measured by CEM and MACS methods, and as calculated based on complete conversion of fuel sulfur to SO ₂	5-7
5-5. Volatile organic compounds for which samples were analyzed	5-11
5-6. Semivolatile organic compounds for which samples were analyzed	5-12
5-7. Semivolatile organic compounds detected in the flue gases of the three fuels	5-15
5-8. Measured and calculated emission factors and percent recoveries for 12 metals	5-19
5-9. Results of XRF analyses of untreated filters and samples	5-20
5-10. XRF analyses of untreated and treated filters loaded with PM from the three fuels	5-21
5-11. Emission factors for CO, NO, SO ₂ , and PM from the three fuels tested	5-21
6-1 Physicochemical characterization of collected PM _{2.5} oil fly ash samples and Arizona road dust particles	6-2
6-2 Biomarkers of pulmonary acute toxicity or injury	6-3
6-3 Relative toxicity of oil fly ash and dust exposures at the lowest observed effect level (LOEL) for each endpoint	6-3
8-1. Summary of risk estimates from inhalation exposure to priority HAPs for 137 oil fired utility boilers in the U.S.	8-12
9-1. Ranges of trace element concentrations in coals	9-2
9-2. Range of selected average trace element concentrations for U.S. coals from different regions of the country, and maximum and minimum concentrations from individual samples	9-3
9-3. Range of averages and reported typical values of trace element concentrations in residual fuel oils from different sources	9-3
9-4. CO emission factors for coal, fuel oil, and natural gas	9-9
9-5. SO ₂ emission factors for three coal types and for No. 6 fuel oil	9-12
9-6. Filterable PM emission factors for different fuels and different combustion system designs	9-13
10-1. Data quality indicator goals for critical measurements	10-2
10-2. CEM full-range and mid-range span check results	10-3
10-3. CEM system bias check results	10-4
10-4. VOC target analytes and method detection limits	10-5
10-5. VOC surrogate recovery results	10-6
10-6. VOC matrix spike and matrix spike duplicate results	10-6
10-7. SVOC matrix spike and matrix spike duplicate results	10-7
10-8. SVOC pre-extraction surrogate recovery levels	10-8
10-9. Pre-sampling surrogate recovery/XAD samples	10-10
10-10. Internal laboratory QC summary	10-11
10-11. Spiked metal sample recoveries	10-13